Naval Fuels & Lubricants
Cross Functional Team
Test Report

Impact of 50% HRD-76 on Middle Distillate Fuel Filtration and Coalescence

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TABLE OF CONTENTS

LIST OF TABLES

Table **Title** **Page**

LIST OF FIGURES

Figure **Title** **Page**

EXECUTIVE SUMMARY

In October 2009, Secretary of the Navy Ray Mabus directed the Navy to decrease its reliance on fossil fuels. The Secretary set a goal of operating with at least 50% of energy consumption coming from alternative sources by 2020. He also set forth the goal of demonstrating a Great Green Fleet, operating on 50% alternative fuel, by 2012 and deploying by 2016. The use of alternative/petroleum sourced aviation fuel blends is a critical component to achieving these goals. The alternative sourced fuels will come from non-food sources and must be compatible with all existing hardware without compromising performance, handling or safety. The increased use of alternative sources to produce Naval tactical fuels will increase the Navy's energy independence while improving national security, decreasing environmental impact and strengthening the national economy. The objective of this test program is to ensure that all proposed alternative fuels perform equally or better than existing petroleum sourced fuels.

Hydroprocessed renewable F-76 (HRD-76) is one such fuel that is derived from non-petroleum sources. HRD-76 utilizes a renewable feedstock of biomass derived oils. The Navy is in the process of qualifying a 50%/50% (by vol.) F-76/HRD-76 blend for use as an alternate to 100% petroleum derived F-76. In order for 50%/50% F-76/HRD-76 blend to be considered a drop-in replacement for petroleum derived F-76, the 50%/50% F-76/HRD-76 blend must be compatible with all current fuel system components including filter/separators.

The single-element test (SET) is a fit-for-purpose test that evaluates the compatibility of new additives and fuel compositions with filter/separator systems currently in use by the fleet. The SET evaluates the ability of filter/separators to remove solid contaminant levels of 72 mg/gal and water levels as high as 30,000 ppm. By measuring the concentration of contaminant in the effluent fuel stream, the impact of the 50%/50% F-76/HRD-76 blend on the filter/separator's performance can be determined.

A 50%/50% F-76/HRD-76 blend was found to have no negative impacts on filter/separator performance. No effluent samples exceeded the effluent free water concentration limit established in Chapter 541 of the Naval Ships' Technical Manual (NSTM) of 40 ppm for free water. No effluent sample exceeded a sediment concentration of 5.0 mg/L and the average sediment concentration measured during the solid injection phase was 0.44 mg/L.

LIST OF ACRONYMS/ABBREVIATIONS

ASTM .... American Society for Testing and Materials

F-76 .... USN F-76 Grade Diesel Fuel

HRD-76 .... Hydroprocessed Renewable F-76

NSTM .... Naval Ships' Technical Manual

PPM .... parts per million by volume

GPM .... gallons per minute

SET .... Single Element Test

DEFINITIONS

Biomass ....plant material, vegetation, or agricultural waste used as the feedstock in the production of fuel

Coalescence ....the ability to shed water

Effluent ....stream leaving a system

Turnover ....time required to flow the entire volume of fluid in a container, also known as residence time (volume of fuel ÷ volumetric flow rate)

Impact of 50% HRD-76 on Naval Distillate Fuel Filtration and Coalescence

1.0 BACKGROUND

In October 2009, Secretary of the Navy Ray Mabus directed the Navy to decrease its reliance on fossil fuels. The Secretary set a goal of operating with at least 50% of energy consumption coming from alternative sources by 2020. He also set forth the goal of demonstrating a Great Green Fleet, operating on 50% alternative fuel, by 2012 and deploying by 2016. The use of alternative/petroleum sourced aviation fuel blends is a critical component to achieving these goals. The alternative sourced fuels will come from non-food sources and must be compatible with all existing hardware without compromising performance, handling or safety. The increased use of alternative sources to produce Naval tactical fuels will increase the Navy's energy independence while improving national security, decreasing environmental impact and strengthening the national economy. The objective of this test program is to ensure that all proposed alternative fuels perform equally or better than existing petroleum sourced fuels.

Hydroprocessed Renewable F-76 (HRD-76) is one such fuel that is derived from non-petroleum sources. HRD-76 utilizes a renewable feedstock of biomass derived oils. These oils are refined using traditional hydroprocessing techniques to produce a useable fuel. HRD-76 refers to the particular cut of the refined product, which has properties comparable to naval distillate fuel F-76.

The Navy is in the process of qualifying a 50%/50% (by vol.) F-76/HRD-76 blend for use as an alternate to 100% petroleum derived F-76. In order for 50%/50% F-76/HRD-76 blend to be considered a drop-in replacement for petroleum derived F-76, the 50%/50% F-76/HRD-76 blend must be compatible with all current fuel system components including filter/separators.

Filter/separators are commonly used onboard naval vessels and at shore stations to reduce solid and free water contamination to acceptable levels. As specified in MIL-DTL-16884M, the maximum allowable level of solid contamination in F-76 grade fuel is 10 mg/L. Chapter 541 of the Naval Ships' Technical Manual (NSTM)[1] allows a maximum free water concentration of 40 ppm and a maximum sediment concentration of 2.64 mg/L at the outlet of shipboard filter/separators.

2.0 OBJECTIVE

The objective of this test was to determine the effects of a 50%/50% F-76/HRD-76 blend on the performance of filter/separators.

3.0 APPROACH

3.1 Test Fuel

The 50%/50% F-76/HRD-76 blend used in this testing met all the physical and chemical properties defined in MIL-DTL-16884M. No additives were added or removed from the test fuel. The 50%/50% F-76/HRD-76 test fuel was stored in an epoxy lined aboveground storage tank

until the time of testing. Prior to starting the test, the tank's sump was drained of any water bottoms and the test fuel was filtered through a filter/separator housing for two turnovers to produce a baseline fuel containing <0.50 mg/L of sediment and <5.0 ppm free water.

3.2 Test Overview

Testing was conducted in accordance with sections 4.3.2.4, 4.3.2.5, 4.3.2.6, 4.3.2.7, and 4.3.2.8 of EI 1581 5th Edition[2] for type S filter/separators. These test conditions are summarized in Table 1. A 5 minute transition period occurred between each phase of testing (not shown in Table 1).

Table 1. Test Overview

Phase	EI 1581 5th Edition	Duration, mins	Cumulative Time, mins	Contaminant Level
Element Conditioning	4.3.2.4.2	30	0-30	No Contaminant Added
Start-Up	N/A	10	35-45	No Contaminant Added
Low Water Coalescence	4.3.2.5.1	30	50-80	100 ppm
Solids Holding	4.3.2.6.1	75	85-160	72 mg/gal
Low Water Coalescence	4.3.2.7.1	150	165-315	100 ppm
High Water Coalescence	4.3.2.7.2	30	320-350	30,000 ppm
Final Inspection	4.3.2.8	N/A	N/A	N/A

Due to system constraints, the element was conditioned for 30 minutes at a flow rate of 15 gpm instead of the 3 gpm flow rate prescribed in section 4.3.2.4.2 of EI 1581. An I-620MM coalescer and TE01-87 separator from Velcon Filters Incorporated qualified to MIL-QPL-32148[3], were used as test elements. Throughout the duration of the test, the fuel flow rate was maintained at 100% of the element's rated flow for F-76, 15 gpm.

The addition of 100 ppm and 30,000 ppm water was achieved by injecting 5.7 mL/min and 0.45 gpm of water, respectively. To ensure sufficient mixing, the water was injected upstream of the centrifugal supply pump. Effluent free water concentration measurements via American Society for Testing and Materials (ASTM) method D3240 was not applicable for this testing due to the dark color of the diesel fuel which interfered with the fluorescence of the detector pads. Therefore, the total water concentration of the filter/separator effluent fuel stream was measured per ASTM D6304 during the water coalescence phases of testing. The free water concentration of the effluent stream was determined by taking the difference of the fuel's water saturation point and the effluent's total water concentration. The fuel's water saturation point was determined using an in-house test method (see Appendix A). In this method, the water concentration of the test fuel was measured downstream of a filter separator as water was injected upstream of the filter/separator. During the saturation evaluation, no particulate contamination was injected. By performing the water saturation test and filtration/coalescence

test separately (i.e. a new filter and separator for each test); an accurate saturation point could be determined.

The solids injection rate of 72 mg/gal was attained by injecting the test fuel with a concentrated fuel and dirt slurry (4.32 g dirt/gal). A 10% by weight Copperas Red Iron Oxide R-9998 and 90% by weight Arizona Test Dust ISO 12103-1 mixture was used as the solid contaminant. The concentrated slurry was injected at a rate of 0.25 gpm upstream of the filter/separator housing. The solid concentration of the filter/separator effluent fuel stream was measured per ASTM D2276 during the solids holding phase.

Due to a limited tank availability, a single pass of the test fuel through the filter/separator as required by EI 1581 was not possible. The risks associated with recirculating the fuel such as introduction of additional contamination and degradation of the fuel were mitigated by filtering the fuel through an additional filter/separator housing prior to the fuel returning to the supply tank in addition to using 10,000 gallons of test fuel. The total volume of fuel used during this test represents only a 53% turnover of the 10,000 gallons of 50/50 F-76/HRD-76 in the supply tank.

3.3 Acceptance Criteria

In order to successfully pass the single-element test, the differential pressure across the filter/separator shall not exceed 6 psi with clean dry fuel, 15 psi before 50 minutes of continuous solids addition at a rate of 72 mg/gal, and 45 psi before 75 minutes of continuous solids addition at a rate of 72 mg/gal. These pressure requirements align with established filter/separator design requirements outlined in MIL-PRF-32148[4].

The average weight of solids in the effluent fuel samples shall not be greater than 2.64 mg/L and the weight of solids in any single sample shall not be greater than 5.0 mg/L. The free water concentration in the effluent fuel samples shall be less than 40 ppm. Effluent solid and free water concentrations align with filter/separator effluent line limitations outlined in Table 541-10-3 of NSTM Chapter 541.

4.0 DISCUSSION

A water saturation point of 42.0 ppm was determined from the water saturation testing (see Appendix A). Based on this saturation point, the calculated free water concentration of the effluent fuel samples is shown in Figure 1. At no point during the test did free water concentration in the effluent sample exceed 40 ppm.

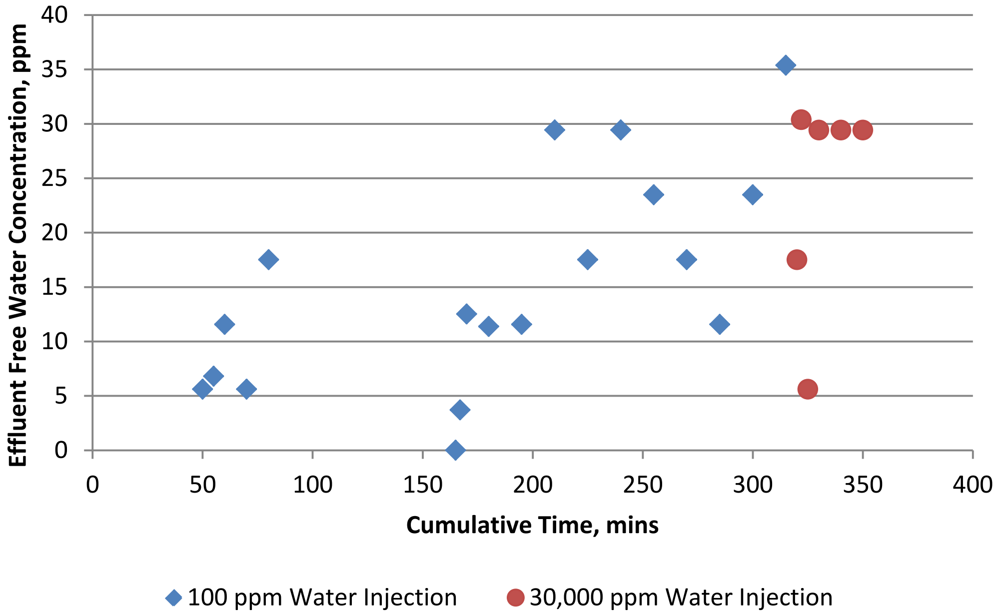

Figure 1. Effluent Free Water Concentration

The results from the solid holding phase of testing can be found in Figure 2. The average concentration of solids measured in the effluent fuel stream during the solids holding phase was 0.44 mg/L. No sediment was measured in the effluent fuel stream during the solids holding phase prior to performing a stop/start flow interruption. After performing a stop/start, two samples having a sediment concentration of 2.19 mg/L and 2.24 mg/L were measured.

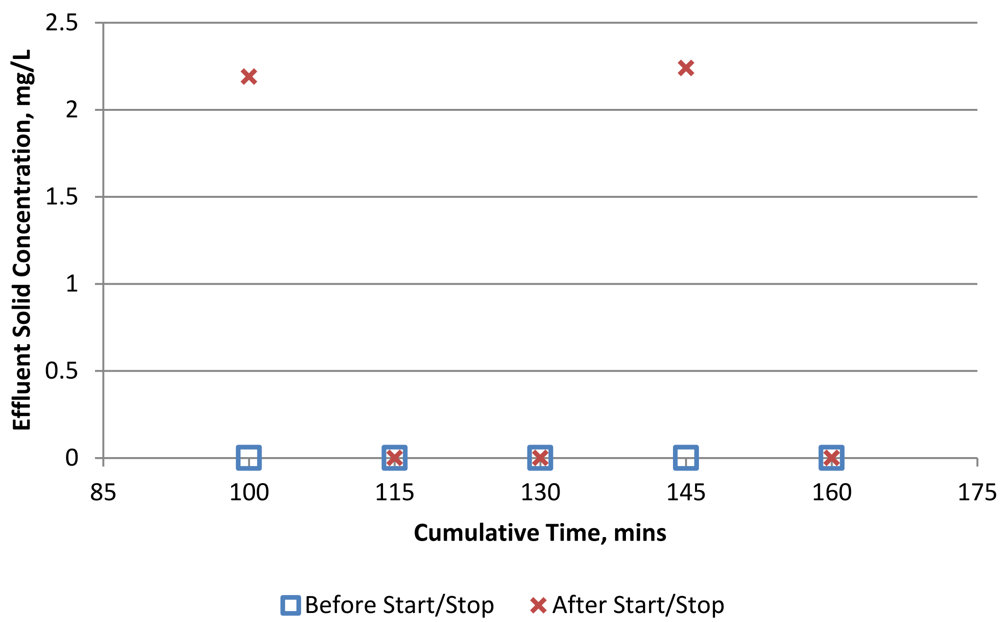

Figure 2. Effluent Particulate Contamination

At no point during the test did the differential pressure across the filter/separator housing exceed 5 psi. All test data can be found in Appendix B.

5.0 CONCLUSIONS

50%/50% F-76/HRD-76 satisfactorily met all acceptance criteria stated in section 3.3. 50%/50% F-76/HRD-76 blend has no negative impacts on filter/separator performance and is compatible with current filter/separator infrastructure.

6.0 RECOMMENDATIONS

It is recommended that 50%/50% F-76/HRD-76 blend be approved for use with EI 1581 5th edition and MIL-PRF-32148 qualified filter/separators.

7.0 REFERENCES

1. *Naval Ships' Technical Manual Chapter 541 Revision 5*. U.S. Department of Defense, August 2007
2. *EI 1581 5th Edition Specifications and Qualification Procedures For Aviation Jet Fuel Filter/Separators*. Energy Institute, July 2002
3. *QPL-32148: Filter Separator Elements, Fluid, Pressure, Aviation and Distillate Fuel, Naval Shipboard*. U.S. Department of Defense, April 2010
4. *MIL-PRF-32148 Performance Specification Filter Separator Elements, Fluid, Pressure, Aviation and Distillate Fuel, Naval Shipboard*. U.S. Department of Defense, July 2005

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APPENDIX A

DETERMINATION OF WATER SOLUBILITY IN NAVAL DISTILLATE FUELS

Objective: To determine the solubility of water in 50/50 F-76/HRD-76

Approach: 50/50 F-76/HRD-76 was flowed through a filter/separator housing while a controlled amount of water was injected into the fuel upstream of the filter/separator housing. A new I-620MM filter/coalescer and TE01-87 separator from Velcon Filters Incorporated were used as the test elements. Prior to injecting free water, the coalescer and separator were conditioned for 30 minutes by flowing 50/50 F-76/HRD-76 through the test housing at a flow rate of 15 GPM. After the 30 minute conditioning phase, 50/50 F-76/HRD-76 was pumped through the filter/separator housing for an additional 30 minutes so baseline total water concentrations could be measured IAW ASTM D6304. Next water was injected upstream of the filter/separator housing at a concentration of 150 ppm for 30 minutes. The total water concentration of the influent and effluent streams were measured IAW ASTM D6340. Lastly, water was injected upstream of the filter/separator housing at a concentration of 3% for 30 minutes. Again, the total water concentration of the influent and effluent streams were measured IAW ASTM D6340 every 15 minutes.

Table A-1. Water Saturation Test Results

Test Phase	Time, min	50/50 F-76/HRD-76 Flow Rate, gpm	Inlet Water Concentration, ppm	Outlet Water Concentration, ppm	Temp, °F
Element Conditioning	0	16.38	-	-	89.1
	30	15.17	11.8	11.8	88.9
Baseline	0	-	-	-	-
	15	15.17	62.7	36.7	88
	30	15.17	23.5	49.0	87
Water Coalescence, 150 ppm	0	15.18	188.9	43.1	87.4
	15	15.18	141.1	19.6	85.3
	30	15.18	147.0	51.0	84.7
	45	15.18	137.2	58.8	83.8
Water Coalescence, 3%	0	15.17	Visible Water	37.2	83.2
	15	15.17	Visible Water	49.0	82.8
	30	15.17	Visible Water	35.3	83.5

Conclusion: The average outlet total water concentration measured during the water injection phases was 42.0 ppm. Since coalescer and separator elements are unable to remove dissolved water, 42.0 ppm represents the saturation point of 50/50 F-76/HRD-76.

APPENDIX B
TEST RESULTS

Table B-1. Test Results

Phase	Cum. Time, min	Fuel Flow Rate, gpm	ΔP, psi	k, pS/m	Outlet Total Water Conc, ppm	Free Water Conc, ppm	Solids Conc, mg/L	Temp, °F
Element Conditioning	0	15.17						
	30	15.17						
Start-Up	35	15.17	2.5					
	45	15.17	2.5					86
Water Coalescence, 100 ppm	50	15.17	2.5	6	47.7	5.7		
	55	15.17	2.5		48.8	6.8		
	60	15.17	2.5		53.6	11.6		
	70	15.17	2.5		47.6	5.6		87.5
	80	15.17	2.5	5	59.5	17.5		87.2
Solids Holding, 72 mg/gal	85	15.17	2.5	6				86.4
	100	15.17	2.5				0	
	100 s/s	15.17	2.5				2.19	
	115	15.17	2.5	6			0	84.8
	115 s/s	15.17	2.5				0	
	130	15.17	2.5				0	
	130 s/s	15.17	2.5				0	
	135	15.17	2.5					
	145	15.17	2.5	5			0	83.9
	145 s/s	15.17	2.5				2.24	
	160	15.17	2.5				0	
	160 s/s	15.17	2.5				0	
Low Water Coalescence, 100 ppm	165	15.17	2.5	6	41.7	-0.3		83.6
	167	15.17	2.5		45.7	3.7		
	170	15.17	2.5		54.5	12.5		
	180	15.17	2.5	6	53.4	11.4		83.5
	195 s/s	14.56	2.5		53.6	11.6		
	210	15.17	2.5		71.4	29.4		
	225 s/s	14.56	2.6	5	59.5	17.5		
	240	14.56	2.7		71.4	29.4		83.5
	255 s/s	14.56	2.7		65.5	23.5		
	270	14.56	3	5	59.5	17.5		
	285 s/s	13.95	3		53.6	11.6		
	300	13.95	3		65.5	23.5		
	315 s/s	15.17	3		77.4	35.4		

Appendix B. Test Results Cont'd

Phase	Cum. Time, min	Fuel Flow Rate, gpm	ΔP, psi	k, pS/m	Outlet Total Water Conc, ppm	Free Water Conc, ppm	Solids Conc, mg/L	Temp, °F
High Water Coalescence, 30,000 ppm	320	14.56	3	6	59.5	17.5	[redacted]	83.9
	322	14.56	5	[redacted]	72.4	30.4	[redacted]	[redacted]
	325	14.56	5	[redacted]	47.6	5.6	[redacted]	[redacted]
	330 s/s	14.56	5	7	71.4	29.4	[redacted]	[redacted]
	340 s/s	14.56	5	[redacted]	71.4	29.4	[redacted]	[redacted]
	350	14.56	5	7	71.4	29.4	[redacted]	85

s/s= measurements taken after a stop/start flow interruption

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15. SUBJECT TERMS
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